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TITLE OF THE INVENTION

Automatic Focusing Camera With Moving Mirror Between Fixed Lens And Fixed Image Sensor

BACKGROUND OF THE INVENTION

The present invention is directed to an automatic focusing camera, and more particularly to an automatic focusing line scan camera for use in scanning applications.

In scanning applications, for examples for packages traveling along a conveyor, it is often required that scans be carried out at varying target distances. For example, if a larger package moves along a conveyor beneath a scanner, the distance between the lens of the scanning camera system and the object is shorter than for a smaller package traveling along the same conveyor path. Prior known systems generally provide focusing for the scanning camera by adjusting the position of the lens system or the image sensor to focus the image plane on the senor. However, this can result in higher costs for systems employing movement of one or more lens in order to maintain the optical alignment of the lens relative to one another and the sensor. Additionally, movement of the image sensor can add additional complexity and cost due to the need to provide electrical connections to an from the imaging sensor and to maintain the desired orientation of the sensor over the path of movement.

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It would be desirable to be able to provide adjustment of the object focal length without the need for moving either the lens system (or one or more lenses therein) or the sensor relative to one another in order to provide a simple and reliable automatic focusing system for a camera system, preferably for use in scanning applications.

SUMMARY OF THE INVENTION

Briefly stated, the present invention is an automatic focusing camera which includes an image sensor. A fixed lens system is provided having a lens with an object side and an image side. The fixed lens system is located in a fixed position relative to the image sensor. A mirror is moveably positioned between the image side of the lens system and the image sensor. The mirror is located at an angle such that an image observed through the fixed lens system is reflected toward the image sensor. An actuator is connected to the mirror and moves the mirror relative to the lens system to change a distance between the lens system and the image sensor to adjust an object focal length between an object and the camera.

In another aspect, the present invention provides a method for automatic focusing of a camera having an image sensor and a lens system with an objective lens located at a fixed position relative to the image sensor. The method comprises: (a) providing a mirror moveably mounted between an image side of the lens system and the image sensor; and (b) adjusting the position of the mirror to vary a length of an optical path between the image sensor and the lens system to vary an object focal point on an object being observed.

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BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

The foregoing summary, as well as the following detailed description of the preferred embodiments of the invention will be better understood when read in conjunction with the appended drawings. For the purposes of illustrating the invention, there is shown in the drawings embodiments which are presently preferred. It should be understood, however, that the invention is not limited to precise arrangements shown. In the drawings:

Fig. 1 is a plan view of the automatic focusing camera in accordance with the present invention;

Fig. 2 is a plan view of a second embodiment of an automatic focusing camera in accordance with the present invention;

Fig. 3 is a plan view of the automatic focusing camera shown in Fig. 2 illustrating the shift in the object focal line as the object focal point moves farther from or nearer to the lens system.

DETAILED DESCRIPTION OF THE INVENTION

Certain terminology is used in the following description for convenience only and is not considered limiting. The words "right", "left", "lower", and "upper" designate directions in the drawings to which reference is made. The terminology includes the words specifically noted above, derivatives thereof and words of similar import. Additionally, the terms "a" and "one" are defined as including one or more of a referenced item unless specifically noted.

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Referring to the drawings, wherein like numerals designate like elements throughout, there is shown in **Fig. 1** a preferred embodiment of an automatic focusing camera **10** in accordance with the present invention. Preferably, the automatic focusing camera **10** is a line scan camera and includes an image sensor **12** and a fixed lens system **14** having an objective lens **16** with an object side **16a** and an image side **16b**. The fixed lens system **14** is located in a fixed position relative to the image sensor **12**, for example by fixed mounting of the image sensor **12** and the lens system **14** on a common substrate, for example a circuit board. The fixed lens system **14** has an optical axis **22**. While the fixed lens system **14** is illustrated as including a single objective lens in the first preferred embodiment of the invention **10**, it will be recognized by those skilled in the art from the present disclosure that the fixed lens system **14** may include multiple lenses, depending upon the particular application. However, in accordance with the present invention, it is contemplated that if multiple lens are provided, the lenses would be adjusted to a fixed, in-use position relative to the other lenses as well as the image sensor **12**, and that the automatic focusing of the camera **10** would be carried out without further adjustment to the lens system **14**.

Still with reference to **Fig. 1**, a mirror **20** is positioned between the image side **16b** of the lens system **14** and the image sensor **12.** The mirror **20** is located at an angle such that an image located along the optical axis **22** is observed through the fixed lens system **14** and is reflected toward the image sensor **12.** This is illustrated most clearly by the path of the

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optical axis **22** of the lens system **14** which is reflected by the mirror **20** toward the image sensor **12** generally along a path **32** normal to the face of the image sensor **12**.

An actuator **24** is connected to the mirror **20** that moves the mirror **20** relative to the lens system **14** to change a distance between the lens system **14** and the image sensor **12** to adjust an object focal length between an object (not shown in **Fig. 1**) and the camera **10.** As shown in **Fig. 1**, preferably the mirror **20** is mounted on an arm **28** having a pivot point **30** located along an optical axis **32** of the image sensor **12.** The actuator **24** is connected to the mirror **20** via the arm **28.** Preferably, the pivot point **30** is located on an opposite side of the image sensor **12** from the mirror **20** and is offset sufficiently such that pivoting movement of the arm **28** approximates linear movement over the range of motion for the mirror **20.**

In a preferred embodiment, the actuator **24** is a voice coil. However, those skilled in the art will understand from the present disclosure that the actuator **24** may be constructed as a solenoid or a stepper motor with a lead screw or using any other suitable controllable displacement means. In the first preferred embodiment, the pivot point **30** is formed by a pin connection. However, it will be recognized by those skilled in the art from the present disclosure that the pivot could be provided by a flexible member such as a leaf spring or a living hinge which would provide the additional advantage of biasing the arm **28** in a given direction to maintain greater stability of the mirror **20**, if desired.

As shown in **Fig. 1**, when the actuator **24** is actuated, the arm **28** can be adjusted to a second position, shown in dashed lines as **28'**, moving the mirror **20** to a second position

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shown as **20'** to adjust the length of the optical path between the lens system **14** and the image sensor **12**. This causes the object focal point to vary in a predictable manner as explained in more detail below.

In the preferred embodiment, the focusing mechanism is used in conjunction with a line-scan camera system, such as a line-scan CCD camera as the image sensor **12**. This is due to the fact that if the object plane and the nodal plane of the lens system **14** are parallel, then the image plane at the image sensor **12** must also be parallel to both the object and nodal planes in order for a complete image to be in focus. The pivoting of the mirror **20** in the first preferred embodiment causes the sensor plane to be non-parallel to the lens nodal plane resulting in an out-of-focus condition for all except a single line in the sensor plane across the face of the image sensor **12.** However, as long the image sensor **12** is a single-line sensor located at this line of perfect focus, then the image sensor **12** will see the object without distortion. This is especially useful for scanning applications where a single scan line is generally being observed and imaged by the camera **10**.

Referring now to **Fig. 2**, a second preferred embodiment of the automatic focusing camera **110** is shown. The second preferred embodiment of the automatic focusing camera **110** is similar to the first embodiment **10** and like elements have been designated with the same reference numerals. The differences between the automatic focusing camera **110** of the second preferred embodiment of the invention and the automatic focusing camera **10** of the first embodiment of the invention are explained in detail below.

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In the second preferred embodiment of the invention, the automatic focusing camera **110** includes a mirror **120** which is mounted for generally linear movement parallel to the optical axis **22** of the lens system **14.** Preferably, the mirror **120** is connected to a linear actuator **124** for movement of the mirror **120** from a first position to a second position **120'**, as shown by dashed lines in **Fig. 2**, to change the length of the optical path between the lens system **14** and the image sensor **12.** In the second preferred embodiment of the automatic focusing camera **110**, since the actuator **124** causes the mirror **120** to move linearly along a path generally parallel to the optical axis **22** of the lens system **14**, the object, lens and sensor planes all remain parallel such that the image can be focused on the surface of the image sensor **12**. However, the field of view of the image sensor **12** moves orthogonally to the sensor line as shown in **Fig. 3**. This results in a shift of the object focal line **123** up or down (for example to the position indicated by **123'**) as the focal point moves farther from or nearer to the lens system **14**, respectively. As shown by comparing the first position of the lens **120** in **Fig. 2** with the object focal line **123** in **Fig. 3** versus the second position of the lens **120'** in **Fig. 2** and the second object focal line **123'** in **Fig. 3**, this shift becomes apparent.

While in the second preferred embodiment a line-scan camera is also used as the image sensor **12**, it is also possible to utilize a two dimensional image sensor **12** in connection with the second preferred embodiment since the object, lens and sensor planes all remain parallel to the field of view of the image sensor **12.**

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In use, the position of the mirrors **20**, **120** of the automatic focusing cameras **10**, **110** are adjusted to vary a length of an optical path between the imaging sensor **12** and the lens system **14** to vary an object focal point on an object being observed. In the first preferred embodiment, this is accomplished by moving the mirror about the pivot point **30**, shown in **Fig. 1**, and receiving the image to be scanned on a single line-scan camera, such as a single line CCD camera. In the second preferred embodiment, the mirror **120** is moved linearly along a path parallel to an optical axis **22** of the lens system **14**, as shown in **Fig. 2**, to adjust the position of the mirror **120** in order to focus the object image on the image sensor **12.**

While the preferred embodiments of the invention have been described in detail, the invention is not limited to the specific embodiments described above which should be considered as merely exemplary. Further modifications and extensions of the present invention may be developed, and all such modifications are deemed to be within the scope and spirit of the present invention as defined by the appended claims and all legal equivalents thereto.

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